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Dynamic and Mechanical Properties of Lattice-Resonator Meta-Structures

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Dynamic and Mechanical Properties of Lattice-Resonator Meta-Structures

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Architected metamaterials can exhibit unique and tunable dynamic properties, ranging from band gaps, negative refraction, and topologically-protected modes. Periodicity on the size scale of the wavelength can lead to band gaps, or ranges of frequencies that cannot propagate. However, impractically large unit cells are needed to achieve low frequency band gaps, which are of interest in structural applications where vibration mitigating devices are required. Locally resonant microstructures can lead to low frequency and narrowband band gaps but typically require large masses and soft materials, which limits structural applications that have strict weight and stiffness/strength requirements. Recent work on elastic meta-structures has numerically and experimentally shown that locally resonant inclusions embedded in a 3D printed periodic lattice can lower and widen Bragg scattering band gaps, addressing limitations of purely periodic or purely locally resonant structures [1].

Here we present our work on “dual-functional” meta-structures, by exploring the interaction of their dynamic and static mechanical properties. We take inspiration from the breadth of work on mechanical properties of architected metamaterials, e.g. [2,3] and references therein, and we embed different primitive lattice geometries with a range of mechanical properties into the lattice-resonator framework. We use finite element modeling to numerically analyze the resulting static and dynamic behaviors of these new meta-structures, and we validate these with experiments on 3D printed samples. The relationship between the effective moduli and band gaps in meta-structures with different lattice geometries can be understood through an analysis of longitudinal and shear modal properties of the lattice, as well as interface effects between the lattice and resonator. We introduce efficiency parameters to evaluate the performance of the different meta-structures, in terms of effective moduli and desirable band gap properties.

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